December 17, 1999

MEMORANDUM TO: William D. Travers
Executive Director for Operations

FROM: Samuel J. Collins, Director
Office of Nuclear Reactor Regulation rz/for

SUBJECT: CLOSEOUT OF GENERIC SAFETY ISSUE B-55, "IMPROVED RELIABILITY OF TARGET ROCK SAFETY RELIEF VALVES"

The purpose of this memorandum is to document the resolution of Generic Safety Issue (GSI) B-55, entitled "Improved Reliability of Target Rock Safety Relief Valves." Target Rock safety relief valves (SRVs) are currently installed in 22 boiling water reactors (BWRs), and there have been several occurrences of improper operation both in spuriously opening and blowing down the reactor coolant and in opening at pressures significantly above the technical specification requirements. There are two different designs of Target Rock SRVs. The earlier design is the three-stage SRV which had a history of spuriously opening and failing to reseat during several events in the 1970s. The later design is the two-stage SRV which is a modification of the three-stage SRV and was designed to eliminate the spurious opening and blowing down problem. GSI B-55 was prioritized in 1983 as a "medium" priority issue, based on the concerns with the three-stage SRVs. Beginning in 1978, two-stage SRVs were installed in several BWRs, and during operation and surveillance testing, had problems with opening at pressures exceeding technical specification limits. As a result, the staff also included the two-stage upward setpoint drift problem in GSI B-55 for resolution.

As a result of the actions which have been taken by the BWR Owners Group and the individual licensees involved to improve the performance of Target Rock SRVs, the staff is recommending that GSI B-55 be closed. The basis for the staff recommendation is detailed in the attached closeout report (Attachment 1). In summary, the staff finds that the Owners Group and the licensees have significantly improved the performance of the three-stage and two-stage Target Rock SRVs and are continuing to evaluate and improve the performance of the SRVs, as necessary, with sufficient resources. Therefore, the staff is proposing no new requirements as a result of this issue. If in the future, the staff finds that actions need to be taken to improve the performance of these SRVs, the existing Quality Assurance, Maintenance Rule, and Codes and Standards regulations (i.e., 10 CFR 50 Appendix B, 10 CFR 50.65, and 10 CFR 50.55a) provide the staff with regulatory mechanisms for pursuing additional improvements, if needed, on a plant-specific basis.

The ACRS reviewed the proposed resolution of GSI B-55 and agreed with the staff that it is acceptable to close this issue. The ACRS reported their findings in a letter dated October 8, 1999 (Attachment 2), and the staff responded to the ACRS in a letter dated November 8, 1999 (Attachment 3). As recommended by the ACRS, the staff has included in the closeout report a statistical analysis of the Target Rock two-stage SRV setpoint performance data.

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#1 12/15

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#3, 12/14

MEMORANDUM TO: William D. Travers
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CLOSEOUT OF GENERIC SAFETY ISSUE B-55 - IMPROVED RELIABILITY OF TARGET ROCK SAFETY RELIEF VALVES

1. INTRODUCTION

The pressure relief system of boiling water reactors (BWRs) is designed to prevent overpressurization of the reactor coolant pressure boundary (RCPB) under the most severe abnormal operational transient (closure of the main steam line isolation valves (MSIVs) with failure of the MSIV position switches to scram the reactor). This design function is accomplished through the use of a plant-unique combination of safety valves (SVs), power-actuated relief valves (PARVs), and dual-function safety/relief valves (SRVs) which have both a mechanical self-actuating setpoint function and a power-actuated function.

In addition to the RCPB overpressure protection design functions of the BWR pressure relief system, a specified number of the PARVs or SRVs utilized in the pressure relief system of each BWR facility are used in the automatic depressurization system (ADS), which is one of the emergency core cooling systems. In the event of certain postulated small-break loss-of-coolant accidents, the ADS is designed to reduce reactor coolant system pressure to permit the low pressure emergency core spray and/or low pressure coolant injection systems to function. The ADS performs this design function by automatically actuating certain pre-selected PARVs or SRVs following receipt of specific signals from the reactor protection system.

Certain safety concerns result when: (1) a valve fails to open properly on demand, (2) a valve opens spuriously and then fails to properly reseat, and (3) a valve opens properly but fails to properly reseat. The failure of a pressure relief system valve to open on demand results in a decrease in the total available pressure-relieving capacity of the system to relieve overpressure. Spurious openings of pressure relief system valves, or failures of valves to properly reseat after opening, can result in inadvertent reactor coolant system blowdown with unnecessary thermal transients on the reactor vessel and the vessel internals and unnecessary hydrodynamic loading of the containment pressure-suppression chamber and its internal components. These types of failures could result in increased risk of release of radioactivity to the environs. There have been many occurrences wherein the mechanical setpoint function of Target Rock SRVs did not adequately perform to open and/or reclose as required. Failure of the mechanical self-actuating setpoint function could potentially result in any of these three concerns, but does not affect the capability of the ADS to perform its emergency core cooling function, since the function of the ADS is controlled only by the power-actuated function of the SRVs.

Technical Specifications for BWR plants require that the SRV setpoints meet a specific tolerance applied to the nominal setpoint values. All BWRs initially had Technical Specifications with a +/-1% tolerance for the SRV setpoints, but some plants have applied for, and the staff has approved, a +/-3% tolerance, with justification based on plant-specific analyses.

This report documents the staff findings relative to Generic Safety Issue (GSI) B-55. As discussed below, the staff has evaluated the activities by the industry to improve the reliability of Target Rock SRVs, and has determined that no new requirements are necessary. The staff evaluation is based on the improvements which have been made to these components and future improvements, as necessary, in order to comply with existing regulations.

2. BACKGROUND

There have been a significant number of failures of Target Rock three-stage and two-stage SRVs to open or close on demand in BWR operating experience. Figures 1 and 2 show the two styles of Target Rock SRVs currently in use in BWRs. Figure 1 is representative of a Target

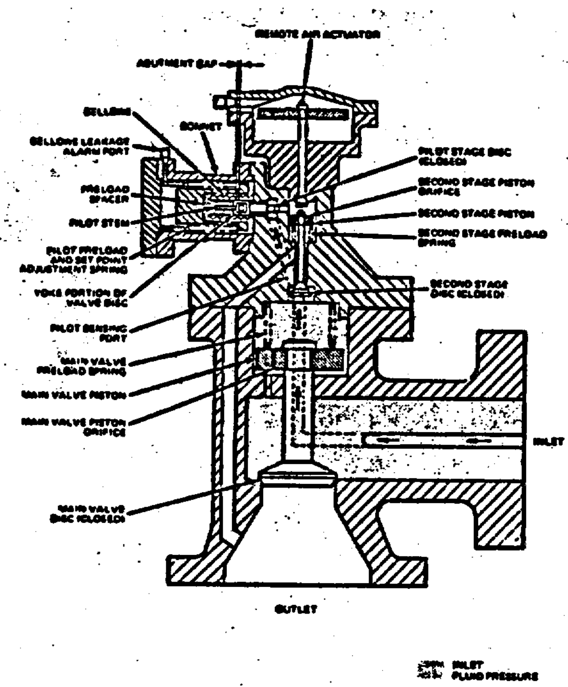


Figure 1
Target Rock Three-Stage SRV

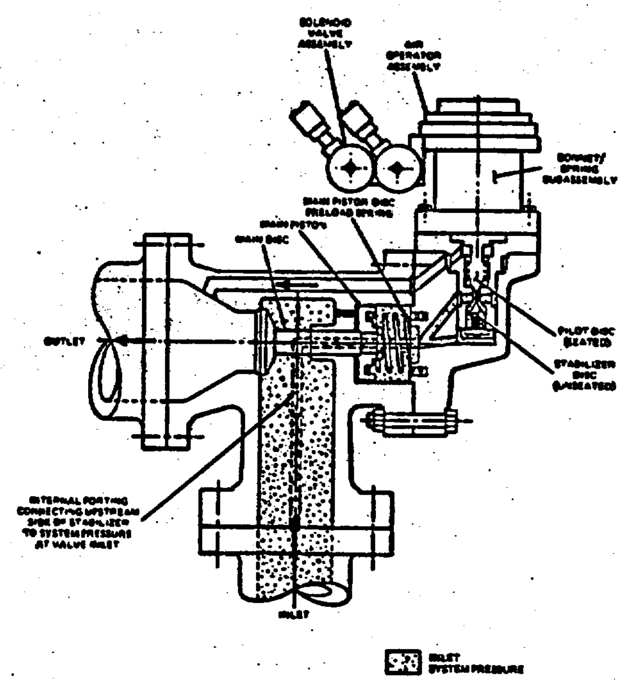


Figure 2
Target Rock Two-Stage SRV

Rock three-stage pilot-operated SRV, and Figure 2 is representative of a Target Rock two-stage pilot-operated SRV. Table 1 lists the BWRs which have three-stage Target Rock SRVs installed, and Table 2 lists the BWRs which have two-stage Target Rock SRVs installed.

<u>Table 1 - Plants With Three-Stage SRVs</u>

Plant	Reactor	Containment	Number of SRVs	SVs	PARVs
Dresden 2 and 3	BWR/3	Mark I	1	8	4
Duane Arnold	BWR/4	Mark I	6	2	-
Limerick 1 and 2 *	BWR/4	Mark II	14	-	-

Monticello	BWR/3	Mark I	7	-	-
Peach Bottom 2 and 3	BWR/4	Mark I	11	2	-
Quad Cities 1 and 2	BWR/3	Mark I	1	8	4
Vermont Yankee	BWR/4	Mark I	4	2	-

* Note - Since initial startup, both Limerick 1 and 2 have operated with two-stage SRVs, but are installing three-stage SRVs during recent and upcoming outages.

Table 2 - Plants With Two-Stage SRVs

Plant	Reactor	Containment	Number of SRVs	SVs	PARVs
Browns Ferry 2 and 3	BWR/4	Mark I	13	-	-
Brunswick 1 and 2	BWR/4	Mark I	11	-	-
Cooper	BWR/4	Mark I	8	3	-
Fermi 2	BWR/4	Mark I	15	-	-
FitzPatrick	BWR/4	Mark I	11	-	-
Hatch 1 and 2	BWR/4	Mark I	11	-	-
Hope Creek	BWR/4	Mark I	14	-	-
Pilgrim	BWR/3	Mark I	4	2	-

The Target Rock three-stage valve predates the two-stage modification, and in the 1970s, experienced numerous failures which involved opening spuriously and/or failing to properly reseat. In NUREG-0462 "Technical Report on Operating Experience With BWR Pressure Relief Systems", dated July 1978, it was reported that there had been 48 inadvertent blowdown events which resulted from a spurious opening and/or a failure to reclose of a three-stage SRV. The three-stage SRV has a pilot (or first) stage which controls the mechanical setpoint and an intermediate second stage which actuates the main stage. The three-stage SRV is known to be sensitive to spurious opening due to pilot leakage. Target Rock has stated that with as little as 25 pounds per hour pilot valve steam leakage, the three-stage valve could experience a spurious opening. NUREG-0462 also reported that there had been a total of 17 failures or potential failures of a three-stage SRV to mechanically self actuate properly due to overpressure. These failures to open all involved leakage or leakage alarms in the setpoint bellows assembly. However, the NUREG concluded that since the bellows assembly of each SRV is continuously monitored for leakage, the likelihood of such failures occurring without being detected is low. Operating history since 1978, indicates that only a few three-stage SRVs have been declared inoperable due to suspected bellows assembly leakage. Consequently, the staff has concluded that with the improved operating and maintenance practices discussed below, there is not a concern regarding three-stage SRVs.

The Target Rock two-stage valve modification was implemented in several BWRs beginning in 1978 to eliminate the spurious openings and premature uncontrolled blowdowns associated with the initial three-stage design. The two-stage valve has a single stage pilot valve installed on the main stage body of the original three-stage valve. The two-stage SRV was also designed without the bellows assembly found in the three-stage design.

It should be noted that, in addition to those in Table 2, five other BWRs have had two-stage SRVs, but three are in long-term or permanent shut down (Browns Ferry 1, Shoreham, and Millstone 1), and Limerick 1 and 2 are having three-stage SRVs installed during recent and upcoming outages. As shown in Tables 1 and 2, there are now a total of 11 BWRs that have one or more three-stage SRVs, and a total of 11 BWRs utilize the two-stage SRV.

It should also be noted that most of the later constructed BWRs, i.e., BWR/5s and BWR/6s, do not utilize Target Rock SRVs. These plants utilize spring-actuated SRVs manufactured by Crosby or Dikkers and are illustrated in Figures 3 and 4. Figure 3 is representative of a Crosby dual-function type spring-loaded direct-acting SRV, and Figure 4 is representative of a Dikkers

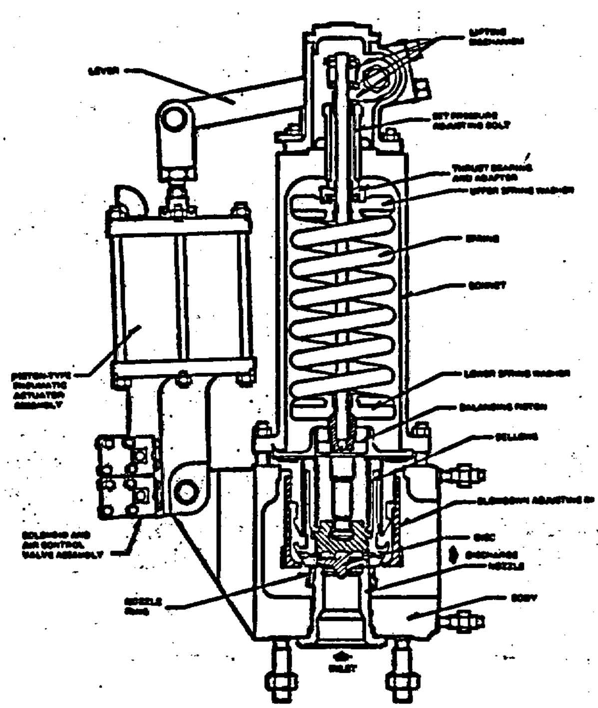


Figure 3
Crosby SRV

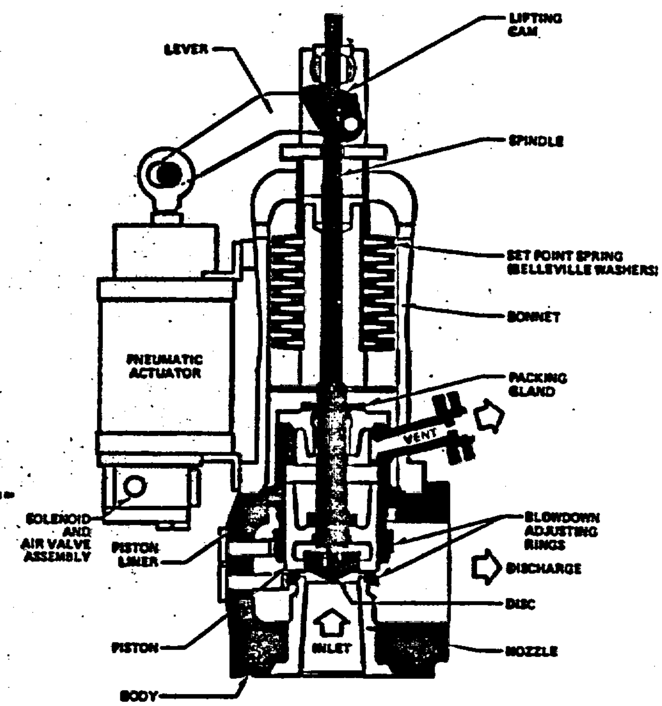


Figure 4
Dikkers SRV

dual-function type spring-loaded direct-acting SRV. There is a significant amount of operating data available for these spring-actuated SRVs which indicates they are not experiencing any of the opening or closing problems as discussed above for the Target Rock SRVs.

The safety concerns associated with three-stage SRVs were identified under Task B-55 in 1978 in NUREG-0471. Using the three-stage valve safety concerns as a base, Generic Safety Issue (GSI) B-55 was prioritized as Medium in NUREG-0933. However, at this same time, problems with the two-stage SRV failing to open on demand had been recognized and were also included in GSI B-55.

3. SIGNIFICANT HISTORICAL OPERATING EXPERIENCE

As shown in Table 1, there are several licensees who did not modify their existing three-stage SRVs to convert them to the two-stage design. For these valves, GE issued a Service Information Letter (SIL) 196, Supplement 3, which recommended increasing the SRV setpoints to raise the simmer margin. Licensees also began implementing more frequent maintenance and testing of three-stage SRVs. These activities were aimed at reducing the pilot seat leakage and have been shown to be effective through successful operating experience during the 1980s and 1990s. Three-stage SRVs have not experienced significant setpoint drift due to pilot disk sticking, and there have not been a large number of bellows assembly leakage occurrences like those which occurred in the 1970s, reported in NUREG-0462. Therefore, with the above improvement to the tendency of the valves to spuriously open and/or fail to reseat due to pilot leakage, no improvements to the design of the valves have been deemed necessary.

Experience to date with the two-stage design indicates that the failures identified above involving spurious opening or failure to reseat are infrequent. The two-stage SRV has been tested with up to 1000 lb/hr pilot valve steam leakage with no significant adverse effect on opening capability. However, an event at the Limerick 1 plant in 1995, resulted in the inadvertent blowdown of a two-stage SRV due to excessive leakage through the pilot seat. It was determined that the leakage was approximately 3000 lb/hr and existed for a significant time period prior to the valve opening. This leakage resulted in significant heatup of the suppression pool, causing plant operators to cycle suppression pool cooling systems. Limerick had experienced leakage of the SRV main stages in the past, due to their unique orientation which caused condensate to collect around the main disk instead of draining. As such, operators did not recognize the leakage as pilot leakage. When the SRV pilot disk eventually eroded away and the SRV inadvertently opened, debris in the suppression pool was loosened and clogged the residual heat removal pump suction strainer. Generic correspondence in the form of an information notice and a bulletin were issued to address the clogging issue and sensitize licensees to excessive SRV leakage (Information Notices 95-47 and 95-47 Supplement 1 and Bulletin 95-02.) The lessons learned from this event relative to SRV leakage were that the two-stage SRVs may be even more tolerant of leakage than earlier tests indicated, and that ample warning in the form of leakage and pool heatup is likely to occur well in advance of an inadvertent blowdown. There have not been similar events for two-stage SRVs at other plants; therefore, it does not appear that these valves have a significant problem with inadvertently opening.

However, two-stage SRVs have exhibited a tendency toward sticking such that they open considerably above nominal setpoints after being in service, i.e., more than 3 percent above nominal setpoint. The most notable event involving this type of failure occurred at Hatch Unit 1 on July 3, 1982, where all 11 valves failed to open at a system pressure up to about 10 percent above their nominal setpoints. The pressure increase was finally terminated when one SRV actuated at about 10 percent above setpoint, followed by the actuation of two more SRVs on the same steam line. There have not been similar events where such a large number of SRVs exhibited this much high setpoint drift, but there have been several events where at least a few two-stage SRVs had setpoints in excess of 10% high. This has resulted in the staff concluding that the sole remaining issue relative to improving the reliability of Target Rock SRVs has been that of reducing the occurrence of pilot disk-to-seat sticking in the two-stage design.

4. BWR OWNERS GROUP AND LICENSEE ACTIONS TO RESOLVE ISSUE

In response to both industry and NRC concerns about the Hatch Unit 1 event, in late 1982, a SRV Setpoint Drift Committee was established by the BWR Owners Group. The SRV Setpoint Drift Committee funded General Electric Co. (GE) to investigate the causes of two-stage SRV setpoint drift. The staff closely monitored the Owners Group evaluation effort. In addition, there were several Information Notices 82-41, 83-39, 83-82, 86-12, 88-30, and 88-30 Supplement 1 which gave the status of the Owners Group proposed resolution to the two-stage valve problems.

On November 10, 1983, the SRV Setpoint Drift Committee, accompanied by representatives from GE and Target Rock, met with the NRC staff to discuss the results of the program. Based on a review of field experience, as-found test data, and some diagnostic tests and metallurgical examinations, GE concluded that two-stage SRV drift resulted from two unrelated causes:

(a) Sticking of the pilot valve disk in its seat, a corrosion-induced mechanism.

(b) Binding of the pilot valve stem if clearances between the stem labyrinth seal and its guide bushing are too small.

GE concluded, based on the available data at that time, that setpoint drift resulting from pilot valve disk sticking accounted for only a small percentage of the drift that had been observed. In order to greatly reduce the occurrence of setpoint drift, GE recommended a revised maintenance procedure be followed that primarily addresses drift resulting from stem binding. GE SIL 196, Supplement 14, describes the revised recommended maintenance procedure. By letter dated June 22, 1984, the BWR Owners Group transmitted to the staff a proprietary topical report NEDE-30476 that documents the information presented at the November 10, 1983, meeting. However, after the November 10 meeting, additional as-found SRV test data revealed that setpoint drift resulting from pilot disk sticking was occurring more frequently than was previously thought.

Based on the additional data, the NRC Staff concluded that the revised maintenance procedure described in NEDE-30476 is a necessary part of resolving the two-stage SRV setpoint drift concern, but it is not sufficient. Setpoint drift resulting from pilot stem binding causes a delay in valve opening; however, the SRV will usually open within five percent of the nominal setpoint. Drift resulting from pilot disk sticking is frequently much more severe, and has been more than 10 percent above the nominal setpoint.

In plants where sticking pilot disks have been experienced, data indicates that, typically, several sticking valves may be expected per fuel cycle. There have been occurrences where there was sticking in excess of the system design pressure, such that it could not be determined how high the setpoint had drifted. Analyses performed by GE and documented in NEDE-30476 indicate that most BWRs have sufficient excess pressure relief capacity such that they would not exceed the applicable ASME Code Upset Condition pressure limit (110% of the system design pressure) with all SRVs drifting high by 10 percent.

For a plant, such as Pilgrim, which has four two-stage SRVs and two spring-actuated safety valves, even two inoperable SRVs means a significant loss of its SRV relieving capacity. Pilgrim is one of three plants that discovered, during surveillance testing in 1984, two SRVs that would not open during as-found testing with steam pressure up to the design pressure of 1250 psig. Based on the results of an independent evaluation performed on one of the stuck SRVs, the Pilgrim licensee concluded that the SRVs had not opened because of oxide binding between the pilot disk and its seat and mechanical interaction between the pilot disk and its seat due to the presence of large carbide particles in the disk microstructure. With Target Rock concurrence, the licensee installed pilot valve disks of a different material. The licensee concluded that the carbide metallurgical structure of the original disk material (Stellite 6B) had an adverse interaction with the seat (Stellite 6) and that by changing to a different disk material (Stellite 21) the adverse binding should be reduced. This modification was performed by the licensee. The detailed results of the independent evaluation have been documented in a proprietary report, copies of which were transmitted to the NRC staff.

In a letter dated March 1, 1985, the staff encouraged the Owners Group to obtain a resolution of the stuck pilot disk concern. The concern about setpoint drift resulting from stuck pilot disks was further reinforced in January 1986, when the licensee for Brunswick 2 reported that, when tested at Wyle Laboratory during the refueling outage, 10 out of 11 two-stage SRVs exhibited sticking of the pilot valve disk to its seat. The resulting setpoint drift ranged from 1 percent to about 18 percent for the eleven valves, with an average of about 13 percent. Testing during previous outages had resulted in many fewer stuck disks. Analyses were performed by GE, taking the large percentage of setpoint drift reported into account. These analyses indicated that for the worst design basis pressure transient, Brunswick 2 would still have met the applicable ASME Code Upset Condition pressure limit.

The Owners Group began a program to resolve the sticking disk concern which included retaining a panel of recognized materials and design specialists to produce new disk material recommendations. At a presentation to the staff on October 17, 1985, the Owners Group presented the results of the panel's research and proposed that a stainless steel (PH 13-8 Mo) be used as a replacement disk material. It was proposed that approximately half of the SRVs receive this new disk during upcoming refueling outages as the valves are refurbished in order to obtain inplant operating experience with this new pilot disc. PH 13-8 Mo stainless steel is a material which has had some application in BWR control rod drive mechanisms and was thought to be much less susceptible to the corrosion-induced type of bonding. New prototype disks were produced and tested successfully by Target Rock. The performance of the SRVs with the new pilot disks were to be monitored and setpoint tested for approximately two to three years during refueling outages. The performance of the SRVs in response to operating overpressure transients was also to be evaluated.

The NRC staff agreed with the Owners Group that the selection of a new pilot disk material for the two-stage SRV, that is not susceptible to bonding chemically to the pilot valve seat, was an acceptable way to resolve the stuck pilot disk concern and complete the resolution of the issues involved in GSI B-55. The information provided by the Owners Group to the staff indicated the new PH 13-8 Mo pilot disk should perform much better than the Stellite 6B disks then being used. During the two to three year implementation period, the Owners Group provided performance and test data to the NRC as it became available. In a letter dated April 2, 1987, the BWR Owners Group noted that a total of 25 pilot disks of PH 13-8 Mo material had been installed in operating BWRs, including Hatch 1 and Brunswick 2, with no reported problems.

In June 1987, promising setpoint test results from the first PH 13-8 Mo disk installed in Hatch 1 were made available. Reports from NRC representatives who witnessed the tests at Wyle Laboratory indicated that there was no disk-to-seat sticking evident. While initial inservice performance of the PH 13-8 Mo disks did indicate a marked improvement over the Stellite 6B disks, additional inservice performance data from Hatch 2, Fermi 2, and Brunswick 2 made it apparent that the PH 13-8 Mo disks were not providing the improved performance that was originally expected.

The BWR Owners Group concluded that the PH 13-8 Mo replacement disks were not a viable solution for eliminating corrosion induced setpoint drift and recommended that PH 13-8 Mo disks no longer be installed to resolve the setpoint drift problem. As a result, at a meeting with the staff on May 1, 1990, the Owners Group proposed a revised action plan to address the setpoint drift issue. The revised action plan proposed two options. The primary option plan modified the pilot disk and seat environment in the SRV by alloying into the Stellite 6B disks a small amount (0.3%) of platinum as a catalyst to recombine high concentrations of radiolytic oxygen and hydrogen that occur in the SRVs. Corrosion-induced oxide bonding was believed to be the root cause of the current setpoint drift problem due to the very high oxygen concentration in the area of the pilot valve disk to seat interface. The Owners Group believed that reducing the amount of oxygen using the alloyed platinum catalyst would mitigate oxide bonding of the pilot disk to its seat and alleviate the setpoint drift concern. The other option plan consisted of a hardware change involving the use of pressure switches to initiate valve opening with the pneumatic actuator when system pressure reaches the switch setpoint. This approach is similar to that used on current BWR/6 plants. The Owners Group planned that if the new platinum alloy disks did not adequately perform, the pressure switch option would be implemented.

By letter dated June 15, 1990, the Owners Group provided written confirmation of their intent to proceed to implement the revised program described at the May 1, 1990 meeting with the staff. The Owners Group indicated that confirmation of the performance of the new disks would take about two operating cycles. The Owners Group also met with the staff on August 1, 1991, and on August 11, 1992, to discuss the progress of the final development of the new catalyst disks and the overall schedule for testing and evaluating them and for implementing the additional pressure switch option. The BWR Owners Group, in parallel with implementing the primary option plan, submitted to the NRC a topical report dated April 11, 1994, for using the pressure switch option. The NRC approved a revised final edition of the topical report on October 24, 1995.

Several licensees installed the new platinum alloy pilot disks, and over the next several operating cycles at various plants, the disks initially provided significantly improved setpoint performance. A meeting was held at the Region I location between the staff and the licensees on April 24, 1996, to discuss the recent performance of the two-stage SRVs and the future actions planned by the Owners Group. At the meeting, the Owners Group expressed that a conclusion regarding the new alloy disks could be made within about a one year period. Then, in a discussion with the staff in May 1997, the Owners Group representatives indicated that several sets of test results had indicated that the new alloy disks had not continued to perform well, and that several valve setpoints were significantly in excess of plant Technical Specifications. However, during the same time period, the Brunswick plant had very good test results with disks which had platinum applied by a different process.

The Brunswick licensee developed a process wherein the disks were coated with a thin layer of platinum implanted onto the disk surface by an ion-beam deposition process. The thin layer of platinum on the disk surface provided a greater surface area of platinum in contact with the oxygen and hydrogen inside the valves than was achieved by the alloyed disks. In addition, the fact that the disk surface is completely coated with platinum, results in the underlying Stellite material being shielded from the corrosive oxygen. As a result, the Owners Group revised its proposed plan to include the ion-beam platinum implanted disks for trial use along with the alternate option of installing pressure switches.

Although not included as one of the Owners Group options, two plants have installed Stellite 21 disks. Pilgrim has used them since 1984 with fairly good results, and Cooper installed them about a year ago with one set of fairly good results. In conversations with the BWR Owners Group, they have indicated that this has not been included as one of the recommended options because Stellite 21 is metallurgically similar to the old Stellite 6B disks and should be similarly susceptible to corrosion and because the Pilgrim operating cycles have been generally shorter than for other BWRs.

5. CURRENT STATUS OF SETPOINT DRIFT ISSUE

As stated above, the BWR Owners Group currently recommends two approaches for resolving setpoint drift in the two-stage SRV caused by corrosion-induced bonding of the pilot disk to its seat: (1) installing new ion-beam platinum implanted pilot disks which reduce the corrosive oxygen content inside the valves, and (2) adding pressure switches to actuate the SRVs by external air power. In addition, two plants have installed Stellite 21 pilot disks.

The status at each of the BWRs having two-stage SRVs is as follows:

Browns Ferry 2 and 3	Additional pressure switches are installed.
Brunswick 1 and 2	Ion-beam platinum disks are installed.
Cooper	Stellite 21 disks are installed.
Fermi 2	Ion-beam platinum disks are installed.
FitzPatrick	Additional pressure switches are to be installed in Fall 2000.
Hatch 1 and 2	Additional pressure switches are installed.
Hope Creek	Ion-beam platinum disks are installed.
Pilgrim	Stellite 21 disks are installed.

Licensees have reported operating experience and the implementation of modifications via several LERs for these plants. In addition, discussions and briefings for both staff and NRR management have been periodically held. The setpoint drift issue has been one issue regularly discussed at BWR Owners Group/NRR Management meetings held several times each year.

5.1 Ion-Beam Platinum Pilot Disks

The setpoint test data to date indicates significantly improved performance with the ion-beam platinum disks. A statistical analysis comparing the performance of the ion-beam platinum and Stellite 6B disks is provided in Appendix A. A total of 46 as-found tests of SRVs installed at Brunswick 1 and 2 and Hope Creek, all indicate no presence of corrosion-induced bonding of the pilot disks. However, there has been an anomaly which has been recently identified. As a result of SRV testing of two-stage SRVs in 1998, three Licensee Event Reports (LERs) were submitted (LER 1999-003-00 for Hope Creek, LER 1998-003-01 for Brunswick 1, and LER 1999-005-00 for Brunswick 2) wherein it was reported that a few SRVs, which had the ion-beam platinum disks installed, had drifted high by up to 4.6%. As a result of the root cause investigations conducted by both licensees, it was determined that the drift was not related to corrosion-induced bonding, but was determined to have resulted from inadequate maintenance practices at the testing facility by Target Rock personnel. The maintenance deficiency ultimately resulted in inadequate clearance between some sliding surfaces in the valve pilot stage. The staff has held discussions with representatives of the BWR Owners Group relative to this experience, and the BWR Owners Group has taken steps to assure that the lessons learned regarding the improvement of maintenance of these SRVs will be incorporated by all affected licensees and maintenance personnel. These steps include audits to be performed by the owners group in late 1999 of the Target Rock corporate facility and of the field activities where testing and maintenance is performed.

The above discussed maintenance practices may have been used for a significant period of time prior to use of the ion-beam platinum disks. Therefore, some of the significant setpoint drift, which has been reported as being caused by corrosion bonding, may have been at least partially caused by the poor maintenance practices. However, the results of various diagnostic tests and observations on high setpoint valves, indicate that corrosion bonding has been the primary cause of most setpoint drift which has been experienced on two-stage SRVs, prior to installing the ion-beam platinum disks. Similar tests and observations of the ion-beam platinum disks have not indicated corrosion bonding. In recent discussions with the staff, the BWR Owners Group stated they would continue to evaluate the ion-beam platinum disks for both the effects of possible corrosion-induced bonding and of improving the maintenance practices to evaluate the long-term success of this modification to the valve design.

5.2 Stellite 21 Pilot Disks

Setpoint data consisting of 43 setpoint tests from Pilgrim and Cooper generally indicate acceptable performance for the Stellite 21 pilot disks. Data from several fuel cycles at Pilgrim have shown significantly improved performance compared to the data for the Stellite 6B disks used there before. The setpoint tolerance provided by the technical specifications at Pilgrim is only +/-1%, and a few as-found setpoints have exceeded this tolerance with one setpoint being significantly higher than any of the others at 9.15%. In LER 1999-004, the licensee stated that an evaluation was being performed to determine the cause of the high setpoint. In a recent discussion with the staff, the licensee indicated that several causes of the drift are being investigated including anomalies associated with the recent plant operational cycles and refueling activities. However, even with this high setpoint, the licensee's experience with the Stellite 21 is significantly better than the previous experience with the former Stellite 6B disks. The licensee performed an overpressure analysis for the as-found setpoints and determined that the peak system pressure would not have exceeded the ASME Code Upset pressure limit of 110% of the design pressure (or 1375 psig). For Cooper, one set of data also indicates significantly improved as-found setpoints. Only one valve at Cooper exceeded the +/-3% Technical Specification criteria and was +5.6% above the nominal setpoint. Cooper LER 1999-004-01 stated that some corrosion-induced bonding could be seen based on a microscopic examination. However, the overall trend at Cooper is also significantly improved over previous experience with the Stellite 6B disks in the past, and the licensee's limiting transient overpressure analysis demonstrates significant margin relative to the ASME Code Upset pressure limit (110% of design pressure) when assuming bounding values of setpoint drift. A statistical analysis comparing the performance of the Stellite 21 and Stellite 6B disks is provided in Appendix A.

5.3 Additional Pressure Switches

While the use of additional pressure switches reliably counteracts the effects of setpoint drift, there are some ASME Code related issues which must be resolved when formally crediting pressure switches for overpressure relief. Only the recent editions (post 1986) of the ASME Code contain provisions for crediting external power sources for actuating the valves, and none of the plants at issue were designed to these Codes. The BWR Owners Group, GE, and Target Rock are currently working with the ASME Code committees to resolve these issues. It is the understanding of the staff that since the later editions of the Code contain provisions for use of external power sources to actuate pressure relief devices, these provisions may be applied if all related requirements of the later Code edition to be referenced are also met.

6. EVALUATION

As described above, the staff finds that no further improvements to the three-stage Target Rock SRVs are necessary at this time. Operating history over the past several years, following improved maintenance, increased simmer margins, and reduced numbers of challenges, has shown the installed three-stage SRVs have acceptable performance.

The prioritization of GSI B-55 in 1983, documented in NUREG-0933, was based on the inadvertent blowdown problems which had occurred for the three-stage valves. The event sequences involving SRVs inadvertently opening and failing to reclose are a subset of the small-break loss-of-coolant accident (LOCA) events. In general, the risk contribution from LOCA sequences is minor for BWRs, since BWRs have several systems for injecting makeup water. However, on an incremental basis, the prioritization of GSI B-55 determined that with a reduction in the frequency of valves failing to reseat by a factor of 4, there would be an estimated reduction of 30 man-rem per reactor-year, which resulted in a Medium priority ranking for this issue. As demonstrated by operational data since the time of the issue prioritization, the reduction in frequency of failure to reseat is significantly greater than a factor of 4. As stated above, there were 48 inadvertent blowdown events prior to 1978, and there have been very few since that time. A review of operating events indicates that there were four inadvertent blowdowns of three-stage SRVs from 1980 through 1983 and one other inadvertent blowdown in 1990. None have occurred since 1990. Therefore, the three-stage SRVs have been improved significantly beyond the assumed improvement used as a basis in the prioritization. In fact, operational history for the past several years, indicates that problems with three-stage SRVs inadvertently opening and failing to reclose has been corrected. This supports the finding that no further improvements to the three-stage SRVs are needed.

The licensee for the Limerick 1 and 2 plants are removing the two-stage SRVs at both of these plants and are installing three-stage valves as replacements. This same licensee has had good experience with the three-stage SRVs installed at the Peach Bottom 2 and 3 plants. Based on the good operating experience with three-stage valves at this plant and at other plants, the staff finds the licensee's modification to be acceptable.

As stated above, the staff has determined that the only remaining issue relative to improving the performance of Target Rock SRVs has been the upward setpoint drift of the two-stage SRVs. After having followed the BWR Owners Group program and the programs of individual licensees for a number of years, the staff is confident that the necessary resources are being allocated by all licensees involved to adequately address the setpoint drift issue. The staff agrees with the current approaches being pursued by the BWR Owners Group and by the individual BWR licensees involving either installing ion-beam platinum disks, installing Stellite 21 disks, or installing additional pressure switches to actuate the SRVs with power. The performance data to date indicates that both the Stellite 21 and the ion-beam platinum pilot disks are performing significantly better than the former Stellite 6B disks with a significantly lesser rate of occurrence of high setpoint drift beyond that allowed by plant Technical Specifications. A statistical analysis comparing the setpoint performance of the Stellite 6B disks with the ion-beam platinum and Stellite 21 disks is provided in Appendix A. The statistical analysis clearly demonstrates that the setpoint performance of both the ion-beam platinum and Stellite 21 disks is significantly better than for the Stellite 6B disks. In addition, analyses of limiting reactor coolant system overpressure transients which have been performed by GE and licensees and reported in plant LERs, demonstrate significant margin relative to the ASME Upset pressure limit of 1375 psig (110% of design pressure), even when assuming bounding values of setpoint drift. Further, the staff has determined that the recent effort by the BWR Owners Group to find the root cause of problems in implementing maintenance practices and determine its generic applicability provides a sufficient level of attention to determine appropriate corrective actions.

For plants which have installed additional pressure switches, the staff recognizes that it will be necessary for licensees to resolve the ASME Code applicability issues if they take formal credit for the switches for pressure relief. However, the staff has determined that since the installation of the pressure switches provides a reliable means of counteracting the effects of corrosion-bonding, it is not necessary for licensees to resolve the Code issues prior to closure of GSI B-55.

To assist in evaluating if additional improvements need to be made to the two-stage SRVs, beyond those already being pursued, the staff performed a bounding assessment assuming that there will continue to be occurrences of significant setpoint drift. There are two types of event sequences involving failures of the valves to open. The first type of event sequence involves inadequate emergency core cooling system (ECCS) flow when SRVs fail to open in the ADS mode. However, since the ADS mode of operation is independent of the mechanical setpoint, these event sequences are not affected by setpoint drift.. The second type of event sequence involves system overpressurization. The most severe overpressurization event is an anticipated-transient-without-scram (ATWS) event involving a main steam line isolation followed by failure of the reactor to scram. As discussed in NUREG-1000, Volume 1, "Generic Implications of ATWS Events at the Salem Nuclear Power Plant", for a typical BWR/4, the peak analyzed pressure for this event is approximately 1300 psig, which is well below the ASME service level C limit of 1500 psig. This analysis assumes that all SRVs open at the correct setpoints; however, even with significant setpoint drift, there is substantial margin. Sensitivity studies of BWR ATWS analysis input parameters (provided in GE proprietary report NEDE-24222, "Assessment of BWR Mitigation of ATWS, Volume II", dated December 1979) show that the effect of a significant loss in SRV capacity still results in the peak pressure not exceeding the service level C limit. Therefore, additional pressure due to upward setpoint drift does not result in a significant loss of margin in the system pressure boundary integrity. This supports the finding that no additional improvements, other than those already being pursued as discussed above, are needed.

As stated above, the only remaining concern relative to the performance of Target Rock SRVs, has been the upward setpoint drift of the two-stage SRVs. However, beyond the activities which are already being pursued by the licensees, the staff has identified no new regulatory requirements which are needed in order to improve the performance of the two-stage SRVs. Because the plant Technical Specifications require these valves to remain operable within the allowed setpoint tolerance, licensees are compelled to find the root causes of poor performance and to take necessary corrective actions. Failure to do so would be a violation of Criterion XVI of 10 CFR 50, Appendix B. Also, the Maintenance Rule (10 CFR 50.65) requires that licensees monitor the performance or condition of components, such as SRVs, against licensee established goals commensurate with safety taking into account industry-wide operating experience. Corrective action must be taken where these goals are not met. In addition, 10 CFR 50.55a, Codes and Standards, references the ASME Code for inservice testing which requires that the causes of failures be determined and corrected. Therefore, 10 CFR 50, Appendix B, 10 CFR 50.65, and 10 CFR 50.55a provide the staff with adequate regulatory mechanisms for requiring further improvements on a plant-specific basis should that be deemed necessary in the future.

7. CONCLUSION

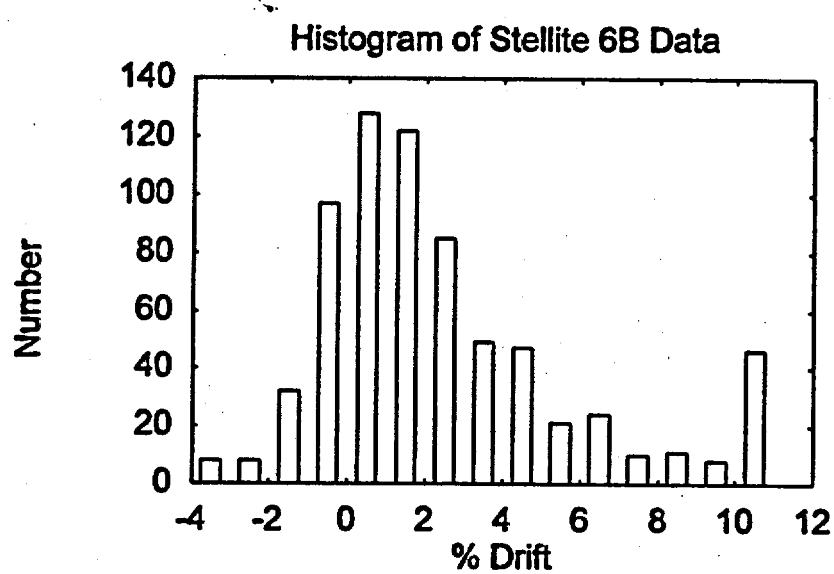
In conclusion, the staff finds that the BWR Owners Group and the individual licensees have significantly improved the performance of Target Rock SRVs, as demonstrated by plant-specific operational experience and test data. As stated above, the inadvertent actuation problems which had existed with the three-stage SRVs have been corrected, and there is substantial margin in the reactor coolant system pressure boundary to accommodate bounding values of setpoint drift for the two-stage SRVs. Further, there are adequate regulatory mechanisms for requiring any further improvements necessary in the future. The staff is also satisfied that the

BWR Owners Group and the licensees are pursuing the setpoint drift issue with appropriate resources necessary to continue to improve performance as needed. Therefore, based on the accomplishments and ongoing activities by the licensees and the BWR Owners Group regarding Target Rock safety/relief valves, the staff is recommending that GSI B-55 be closed.

APPENDIX A

Statistical Analysis of Stellite 6B, Ion-Beam Platinum, and Stellite 21 Disk Setpoint Performance Data

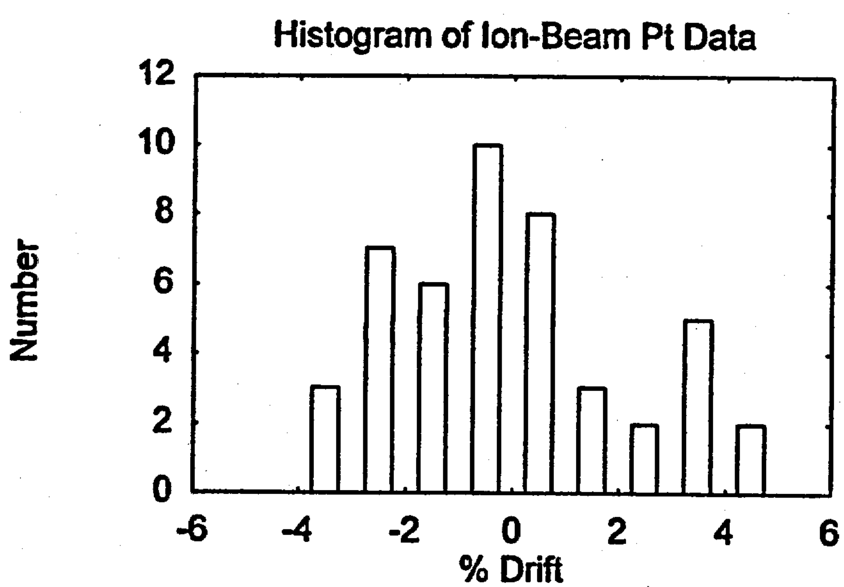
Histograms of the setpoint performance data for the three different disk materials are provided below. The parameters and statistics shown beside each histogram are described below.



$n_x = 696$
$x_m = 2.81\%$
$S_x = 4.38\%$

95% lower $\mu_x = 2.54\%$

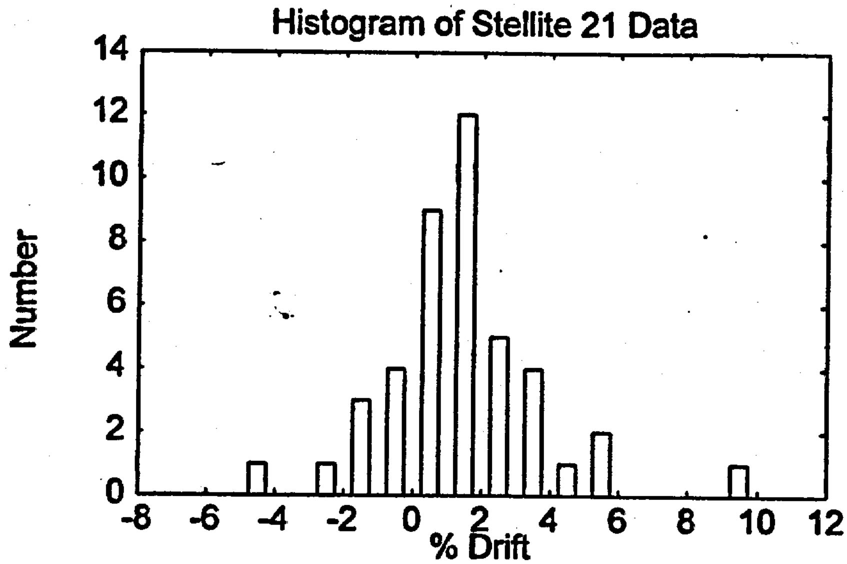
95% UTL = 10.48%



$n_y = 46$
$y_m = -0.054\%$
$S_y = 2.21\%$

95% upper $\mu_y = 0.49\%$

95% UTL = 4.56%



$n_z = 43$
$z_m = 1.35\%$
$S_z = 2.32\%$

95% upper $\mu_z = 1.94\%$

95% UTL = 6.22%

where: n = sample size
x_m, y_m, z_m = means of samples x, y, z
S = sample standard deviation
μ = population mean
UTL = upper tolerance limit

Based on the mean values and standard deviations of the setpoint drift data samples, it can be hypothesized that both the ion-beam platinum and Stellite 21 disks are performing better than the Stellite 6B disks. That is, for the data sets for both the ion-beam platinum and Stellite 21 disks, the average setpoints are closer to the nominal values and there is less spread of the data from the nominal values than for the data set for the Stellite 6B disks. However, there are specific statistical tests, described below, which can be performed to determine if the populations represented by the data samples are significantly different. That is, the question can be answered regarding whether there is significantly improved performance of one disk material over the other, considering the uncertainty associated with the limited number of data points in the samples. NUREG-1475, "Applying Statistics" is used as a reference.

<u>Testing Equality of Means</u>

Student's T statistic (reference: Table T-3, NUREG-1475) is used to test (separately) whether the means of the ion-beam platinum population (represented by sample y) and the mean of the Stellite 21 population (represented by sample z) are significantly lower than the mean of the Stellite 6B population (represented by sample x). In comparing the ion-beam platinum and Stellite 6B disks, the corresponding t statistic (assuming unequal variances) is calculated as 7.83, which is statistically significant ($p < 0.05$). The similar test that compares the Stellite 21 vs Stellite 6B, calculated as $t = 3.73$, also shows the Stellite 21 mean to be significantly lower than the mean of Stellite 6B ($p < 0.05$).

Confidence Interval about the Mean

In addition to the tests stated above, a one-sided 95% confidence limit was constructed for each population mean (reference: Table T-3, NUREG-1475). The 95% lower confidence for the mean of Stellite 6B (calculated as 2.54%) was higher than the upper 95% confidence interval for the mean of the ion beam(0.49%) or the Stellite-21 (1.94%).

Tolerance Limits

Tolerance limits (reference: Table T-11b, NUREG-1475) provide assurance about a proportion of the population. A 95/95 (one-sided) upper tolerance limit (UTL), provides a 95% assurance that 95% of the population of setpoints falls below the UTL. In this study, the UTL was calculated as 4.56% for ion-beam platinum disks and as 6.22% for the Stellite 21 disks. These values are substantially less than the 10.48% calculated for the Stellite 6B UTL.

Testing equality of variances

The F test was used to test whether the variance of the ion-beam platinum population and the variance of the Stellite 21 population are significantly lower than the variance of the Stellite 6B population. In comparing ion-beam platinum and Stellite 6B disks, the corresponding F statistic (Reference Table T-4, NUREG-1475) is calculated as 3.93, which is statistically significant ($p < 0.05$). The counterpart test for the Stellite 21 vs Stellite 6B, calculated as $F = 3.56$, also shows significant variance differences ($p < 0.05$). Hence the variance (and the standard deviation) of both the ion-beam platinum and the Stellite 21 populations are smaller than that of the Stellite 6B population.

Summary

In summary, based on the above T and F statistical tests, the setpoint drift means and standard deviations for the ion-beam platinum and Stellite 21 disks are significantly less than the setpoint drift mean and standard deviation for the Stellite 6B disks. In addition, the computed 95% upper tolerance limits for both the ion-beam platinum and Stellite 21 disks are substantially less than for the Stellite 6B disks.